

The use of QTVR for teaching Radiology and Diagnostic Imaging

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Abstract This paper reports on the preparation of a technology-mediated alternative to print-based external study of a postgraduate unit in veterinary diagnostic imaging. A number of innovative uses of technology had to be developed in order to meet the educational requirements:

- Large radiograph images were converted into QuickTime VR format, which enabled them to be zoomed into and navigated, with significant savings in file size. The authors are unaware of any similar application of QTVR to flat images;
- An electronic whiteboard was developed using multi-user ShockWave, which enabled users to share and annotate QTVR images across the internet, while still retaining the QTVR navigation functions;
- A FileMaker Pro database was used to maintain details of images and associated clinical information;
- Web pages were generated from the database as interactive case studies, delivered on CD.

The conference presentation will demonstrate how these technologies are linked together in novel ways to meet the learning needs of the students.

Keywords: Veterinary, radiography, ultrasound, case studies, QTVR, multi-user ShockWave, electronic whiteboard

Introduction

This paper reports on the innovative use of QuickTime Virtual Reality (QTVR), multi-user ShockWave and web databases in a CD-ROM-based database of radiographs (X-rays) and ultrasound images, for use in the Veterinary Diagnostic Imaging (V620) unit in the Master of Veterinary Studies offered by Murdoch University. The Master of Veterinary Studies is an advanced coursework Masters degree available internationally through distance education, and targeted at professional veterinarians in practice. In the past, the Masters was offered solely in print format, but, increasingly, electronic and online aspects have been added.

V620 is fundamentally a practical unit, with students required to work with and diagnose radiographs and ultrasound images. In external, print-based mode, this led to several problems:

- the costs and inconvenience of bulky study materials and teaching aids sent to students in remote locations;
- delays in feedback to students working on case-based problems;

- difficulties in communicating with students having difficulties with images.

Veterinary Diagnostic Imaging includes four sections:

- radiographic technique and ultrasound principles;
- the imaging and interpretation of, in small animals:
 - the skeletal system;
 - the abdomen;
 - the thorax.

The major teaching strategy is for students to work on case studies in their coursework and assessment, using large numbers of radiographs and ultrasound images demonstrating different patterns of disease in the various anatomical regions. The case studies are supported by print-based materials. By using the radiographs and ultrasound images, students learn the principles of recognising normal and abnormal structures and learn to define the patterns of change present in disease processes, and make diagnoses from these. If students experience difficulties in recognising radiographic or ultrasound changes or diagnosing an abnormality, they need to be able to discuss this with their lecturer.

Students work through non-assessable worked case studies in each section, and then undertake marked case evaluations using radiographs or ultrasound images and complete case-related assignment questions.

The Teaching and Learning Problem

In offering V620 in external mode, there are several ongoing practical problems. These have been discussed in more detail in Phillips, Pospisil & Richardson, (2000) and Phillips, Pospisil & Richardson (2001), and are summarised below.

High costs and administrative load in producing and distributing radiographs.

In 2000, it cost \$2,748 to produce each new set of hard copy materials, and the average cost of providing radiographs to students was \$334 per student, mainly in postage costs.

The inconvenience to students of handling and transporting bulky radiograph files.

The package of materials sent to students is of the order of 43cm x 35cm x 30 cm in size. The use of hard copies of images means that students require access to a viewbox, usually located at the veterinarian's workplace. However, most students preferred to do their coursework from home. They found the transportation of radiographs in bulky files from one location to another to be a considerable inconvenience.

Teaching problems caused by lack of interaction between teacher and student.

The external mode presents difficulties in achieving a satisfactory level of interaction between teacher and student. There is an unavoidable delay in students receiving feedback on assignments sent by post. In previous years, attempts have been made to improve contact between teachers and students by using email and individual telephone discussions. Teleconferencing has been used for group-based discussion of case study radiographs. However, this proved to be costly and often unsatisfactory, as it was difficult to discuss images without being able to pinpoint or highlight areas of interest.

Requirements for an Electronic Solution

Given the problems with the print-based version of V620, it was thought worthwhile to pursue a technological solution, essentially by making the radiographs and ultrasound images available to off-campus external students in electronic form. Because many students are in extremely remote locations, fast and reliable internet connections could not be relied upon, although it was a condition of enrolment that some form of internet access be available. Therefore, the images were to be provided on CD-ROM.

The requirements of the project are summarised in Table 1. In a nutshell, this project aims to build a system to generate problem-based learning interactive tutorials on demand. The interactive tutorials will provide immediate feedback to student input, and assessable work will be submitted for marking. In addition, an electronic whiteboard is required for discussion of problems students may experience. As much as possible, the system should be able to be maintained by veterinarians, with minimal input from technical staff

There are four major components of the project, which are displayed in column 1 of Table 1. The technical solution chosen for each of these components is given in parentheses, and discussed in detail in the following section. Column 2 of Table 1 summarises the requirements in more detail.

Requirement	Description
Image presentation and format (QTVR)	Radiograph and ultrasound images are to be presented in electronic format images are physically large. File size is potentially a problem the required diagnostic detail within the image must be maintained the normal viewing process for hard copies of radiographs should be simulated at multiple levels including the viewing of images from a distance and close-up, without restricting the decision-making process involved in determining the regions that require further examination in fine detail students need to be able to compare several images at the same time in a similar manner to displaying them side by side on a viewbox students should have flexibility in choosing which images to view images should be clearly labelled to facilitate referencing images are to be delivered on CD
Image storage and maintenance (FileMaker Pro database)	Images should be stored in a database, so that: case details can be associated with images large numbers of images can be maintained lecturers can easily add new cases and images and edit existing cases lecturers can choose which images to use each time the course is offered new CD's can be automatically generated from the database
Interactive case studies (static HTML generated from database using Grab A Site)	Images are to be presented to students as part of case studies, in the form of problems to be solved. case studies will be presented in one or more standard layouts, with contextual information and one or more images. images must be able to be made larger and viewed side-by side in any way the student requires students need the facility to build a report about the case, and to save this for future review and/or marking a self-assessment mode is needed, in which students 'submit' their report, after which a model answer is provided immediately an assessment mode is needed, whereby student reports are submitted to the teacher. most of the features of the interactive case studies will need to be carried out offline, because of network bandwidth and reliability issues.

Addressing student problems (multi-user ShockWave electronic whiteboard)	<p>Facilitate communication, both student-tutor and student-student, about specific features of an image. Both parties need to:</p> <ul style="list-style-type: none"> see the same image on screen at the same time be able to draw on the image to highlight areas of interest, and see what the other has drawn choose another image to view type comments to each other or communicate in some other way <p>An online connection is necessary for this functionality.</p>
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Table 1. Requirements of the project

Implementation

Image presentation and format

Hard copy radiographs are physically large, of the order of 43cm x 35cm (17in x 14in). When viewed at full size, they are larger than a normal computer screen, so some mechanism of moving the image around on the screen is necessary. Furthermore, it is professionally necessary for veterinarians to observe the whole image first, then to focus in on areas of interest. When attempting to apply these techniques with scanned images, it is necessary to be able to zoom out to view the entire image, and zoom in for fine detail.

The interpretation of X-ray images requires fine discrimination between diffuse areas of grey. To replicate this on the computer requires high resolution scanning at high colour depth, and careful attention to brightness and contrast settings to ensure relevant areas are visible. The combination of large physical size and high resolution implies that scanned images would take up large amounts of storage space on the computer. A 17in x 14in radiograph scanned at 300dpi¹ in millions of colours would occupy 63 Megabytes of disk storage, uncompressed. Only a limited number of such images could be stored on a CD-ROM, and opening a single image would place significant load on even the most up-to-date computer. In V620, students are provided with over 300 images.

At first sight, it appeared that it would be impossible to achieve the requirements (large size, high image quality, moving within the image, zooming in and out) with file sizes which were usable on standard personal computers. However, it became apparent that Apple Computer Inc.'s QuickTime Virtual Reality (QTVR) technology (Apple Computer Inc., 2000) might be applicable.

QTVR is a variant of the QuickTime digital video format, allowing the user to experience a form of virtual reality on their computer screen. There are two types of QTVR movies, panoramas and objects. In both panoramas and objects, the QTVR system software enables the user to move and zoom within the image. QTVR also allows important areas of images to be highlighted by hotspots, which enable annotation of images or the inclusion of hyperlinks to web pages or other images.

QTVR objects are created with the camera looking inward, and give the impression that the object being viewed is turning around, as if it is held in your hand. A QTVR object is often created by standing the object on a turntable with a fixed camera location. A series of images of the object is taken, as the turntable is turned in increments.

In a QTVR panorama, the camera is looking outward, and a series of still images are taken through a 360 degree arc. The individual images are stitched together into a single large, flat image. It occurred to us that an X-ray is also a large, flat image, and the image

¹ dpi — dots per inch

manipulation functionality of QTVR might be able to be applied to such images. QuickTime VR also provides inbuilt compression algorithms to reduce image file sizes.

However, the question remained whether QTVR could be persuaded to work with a single image rather than a sequence of images. After some research, we determined we could achieve this by creating a *virtual* QTVR object, with only one frame (setting the horizontal sweep angle to 0 degrees). We were then able to perform a feasibility study to determine whether the image quality was adequate and how great the image compression would be.

An obsolete XRS RSU1 X-ray Scanner (with a resolution of 146 dpi) and the Ray Vision software was used for scanning most large images. The resolution of the images was marginal for some images, particularly for bone detail and ultrasound images. Consequently, some images were scanned with a smaller UMAX A4 flatbed scanner at 300 dpi resolution. This gave a higher resolution, but with the limitation that insufficient light was able to pass through the image to provide the depth of grey scale across the image, to make the features visible. The radiologist needed to perform a quality check on each scanned image and, frequently, several different scans with different contrasts had to be made, to ensure that clinical features were visible. Eventually, the radiologist was satisfied that the scanning and QTVR technique was suitable for all but the abdominal and some thoracic images. However, a higher resolution X-ray scanner would have increased quality and reduced the amount of image preparation time.

Scanned images were 'cleaned up' in Adobe Photoshop, then imported into the VR Worx application to create the QTVR files.

Once it had been established that the approach described here was feasible, the remainder of the images was scanned. Although there were originally 200 hard copies, not all of these were scanned, but some new images were added. In total, 250 images, of varying type, quality and size, were scanned. In some cases, multiple images were displayed on the one X-ray film, but these were produced as separate QTVR files. In total, 319 individual QTVR movies were produced.

The compression offered by QuickTime also resulted in considerable reductions in file sizes. Given that there was a large range of image sizes, the average size of the scanned images was approximately 2Mb, while the average size of the QTVR images was approximately 300kb. This size makes it feasible to deliver images over the web, as well as on CD-ROM.

Image storage and maintenance

A filenames convention was developed for storing and locating the large number of QTVR images. The characteristics of each image are able to be uniquely determined from its filename, and associated directory name. The images were divided up into five major categories, distinguished by a two letter abbreviation:

RT	Radiographic Technique
UT	Ultrasound Technique
SK	Skeletal System
TH	Thorax
AB	Abdomen

A directory was created for each category. Each directory was divided up into subdirectories, also with two-letter abbreviations — for example SK/EX was the Extremities directory of the Skeletal System. Within each directory, files were numbered and annotated with abbreviations for other relevant information.

FileMaker Pro was used as the database engine to store information about each case. FileMaker was chosen because of its cross-platform nature, and the ease with which web pages can be created to display the results of database queries. For each case, the database stores a title, a history and a description of the case. The database also contains four other fields, which contain different aspects of the lecturer's diagnosis of the case. These fields are password-protected and not normally visible to the student. Feasibility studies have been carried out to determine whether it was more appropriate to store the images within the database or to simply record their file locations. The latter is the case in the most recent version.

The FileMaker Pro database is intended principally to act as a managed storage location for the cases and images. A very important design consideration was that the information was not static, and that new images and cases had to be added at will. A password-protected interface was developed which allows radiologists to add and edit cases through the web. The database is thus dynamic, and as new clinical cases become available, they can be readily added, for incorporation in the unit the next time it is offered.

However, we also developed a read-only, online view of the database, whereby students could search out cases and have them presented as web pages. This function has not been used for this purpose, but could be, for on-campus students.

Because of the file sizes and internet bandwidth issues, an online database solution was not appropriate for the target students, at locations all around the world. Instead, the images and case information needed to be delivered on CD-ROM. It was therefore necessary to extract the information from the database into some format suitable for use on CD.

Our initial attempts to transfer the database information onto CD were not entirely successful (Phillips, Pospisil & Richardson, 2000, Phillips, Pospisil & Richardson, 2001). The method currently used is to specify a FileMaker query, such as “view all records sorted by category”, and to create static HTML pages from the result using a utility such as Grab A Site. What was a search query on the live database becomes a browse list on the static CD, but the same material is available to the student. Several different views of the data can be created simply by capturing various search criteria.

Any QTVR images referred to on a page are displayed in moderate size on that page. A link is also present for each image which opens the QuickTime Player, so that images can be compared and resized at will. Other interactivity can be added by embedding Javascript into pages at the time they are created by FileMaker Pro.

Interactive case studies

The CD-based solution described above presents students with static material about cases. Students can interact with the QTVR images, and attempt to make diagnoses. They can explore the images and relevant information can be displayed as hotspots are rolled over within QTVR. However, the CD, as described above, has no facility for the student to check whether they are correct in their diagnosis.

One solution is to embed an interactive track in the QTVR movie, and ask the student to click on areas of clinical interest, in a self-test mode. However, such testing only elicits lower-order knowledge, rather than the higher order diagnosis skills required by this unit.

For the interactive case studies to offer an appropriate learning environment, the student needs to enter their own diagnosis about a case. This may be in the form of a single text field, or as a number of fields in a diagnostic report. Student work needs to be saved for subsequent review.

In self-assessment mode, when a student is satisfied with a diagnosis, they submit their work, and a model answer is displayed for them to compare their work with. In assessment mode, work will be submitted to the lecturer either directly online or through an email attachment.

At the time of writing, a full specification of this functionality has not been finalised.

Addressing student problems

Perhaps the major problem experienced by lecturing staff teaching V620 to external students was the inability to determine whether the student was actually looking at the part of the image that the tutor was talking about. When students had problems with particular images, often the only option open to them was to telephone their tutor. However, with ultrasound and radiograph images, it is often difficult to describe exactly which diffuse area of grey one should look at. Often, many minutes would be spent in conversation, before it was realised that the discussion was about different areas of the image. In a face-to-face situation, on the other hand, a simple pointing gesture would resolve this issue in seconds.

This was the technical problem facing us — how to simulate the face-to-face situation with QTVR images. Electronic whiteboard solutions exist in the market place, but these typically involve static images. In our case, we wanted to be able to use QTVR features, such as panning and zooming, while at the same time being able to highlight key areas on the image.

The solution we chose was provided by MacroMedia's ShockWave Multi-user Server. This is an application which enables ShockWave movies on the web to communicate with each other. The Multi-user server comes bundled with the commercial version of MacroMedia Director. Code for an electronic whiteboard was embedded as a 'behaviour' within Director, and we modified this to work with QTVR.

At the time of writing, the prototype whiteboard enables users to load a QTVR image; zoom and pan within it; draw shapes and lines on it; and type text messages to each other. There is no restriction on the number of people who can interact with the image at the same time, so that it is possible to run tutorial classes as well as one-to-one help sessions with the tool. Users are allocated to groups, so it is possible for several whiteboard sessions to be carried on simultaneously within the class.

A second prototype uses Macromedia Flash as a means of displaying the radiographic images instead of QTVR. This was trialled because of technical problems in propagating messages sent from the built-in QTVR controller to the other participants of the whiteboard session.

The QTVR whiteboard will be progressively refined during the year and will be ready for demonstration at the AUDF conference in September.

Conclusion

This paper describes innovative use of Apple technology in an educationally sound context.

QuickTime VR is used to simulate the process of viewing radiograph and ultrasound images. Images and case information are stored in a FileMaker Pro database. Case studies are created from the database as static web pages and delivered to students on CD ROM. A specification has been given for interactive case studies by which students can gain immediate feedback. An electronic whiteboard is described, which allows students and tutors to manipulate the same image at the same time.

While none of the technology used is new, this paper describes how existing pieces of technology can be linked together in new ways. These developments enable Veterinary Diagnostic Imaging to be taught more effectively and to larger numbers of students, by:

- providing immediate feedback to students;
- easing the burden of marking whilst enriching the learning experience;
- providing more opportunities for communication and discussion of diagnosis;
- enabling dynamic annotation of images;
- enabling case studies to become more challenging and educationally effective.

The approaches being developed in this project have wider applicability in the Master of Veterinary Studies programme at Murdoch University, in which many units are case-based. Indeed, these approaches are applicable to any image-based discipline, particularly those where learning has to occur at a distance.

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